

The Extratropical Tropopause Region in the GMI-FVGCM 2°x2.5° Combo Model: Evaluation with aircraft data sets

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Thanks to Bryan Duncan and the GMI core team.

*Special thanks to Peter Hoor and colleagues at Mainz
for providing both raw and analyzed Spurt aircraft data*

A New GMI Product: 2°x2.5° Combo Model using a 5 years of FVGCM met fields (aka GEOS-4-GCM)

- Model has a combined tropospheric and stratospheric chemical mechanism.
- The CTM is run at higher horizontal resolution than previous tropospheric runs. There are 42 vertical levels (lid at 0.01 hPa).
- The model uses Fast-JX photolysis code (no more stratospheric look-up table).
- Thanks to Bryan Duncan for integrating this simulation. *(availability by ftp – full years or individual months – ask for details)*

Why evaluate the upper troposphere/lower stratosphere ('middleworld')?

- Downward mass flux from this region is a chemical source for the UT. We'd like to know if its chemical composition is realistic.
- The troposphere and stratosphere interact chemically in the tropopause region. We'd like to know if the model UT/LS is physically similar to the real one.
 - How thick is the tropopause layer?
 - What is its meridional extent?
 - Does it have seasonally-varying behavior?

Abundant aircraft data in the UT/LS are available for model evaluation

Trace measurements of CO, CO₂, N₂O, and O₃ were made during 8 campaigns of the 'Spurt' project between 2001-2003.

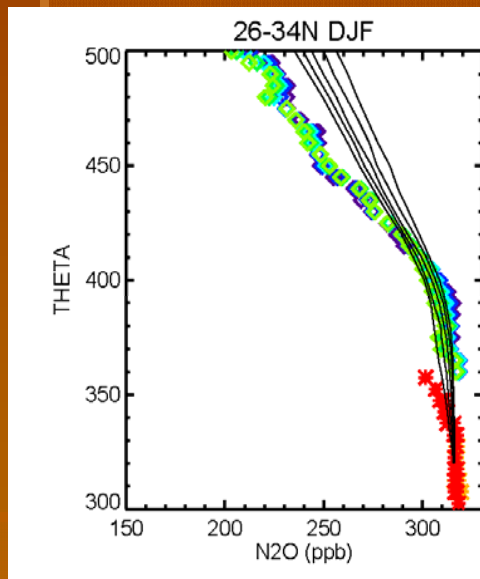
Measurements span ~280-400K, 35°-85°N, and all seasons.

Hoor et al [ACP, 2004] analyzed these data on an equivalent latitude/potential temperature grid. *(Thanks to Peter Hoor (MPI-Mainz) for CO, CO₂, and N₂O. Thanks to M. Hegglin and T. Peter (ETH Zuerich) and C. Schiller (Juelich) for the O₃ data!)*

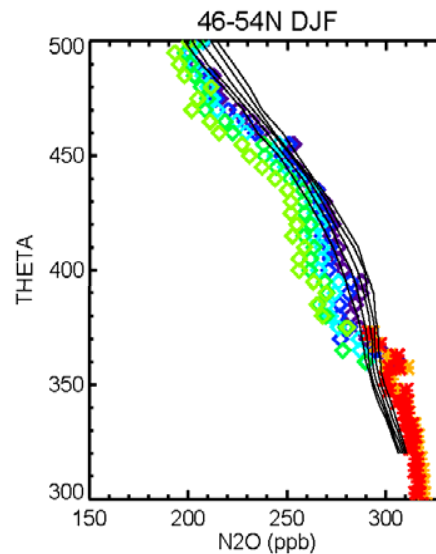
These measurements provide continuity with ER-2 data analyses (N₂O and O₃) spanning 360-500K.

Simple evaluation of composition: Combo N₂O + Spurt and ER-2 Winter Profiles

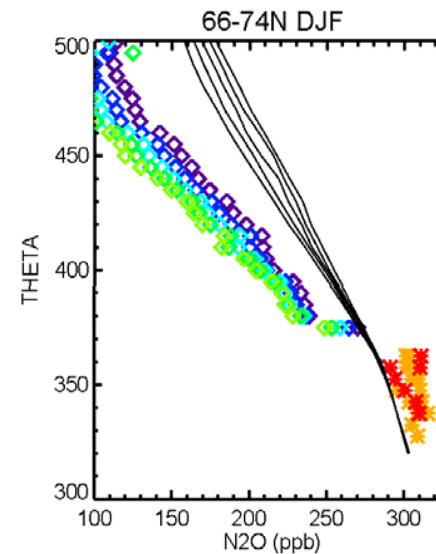
Subtropics



Midlatitudes



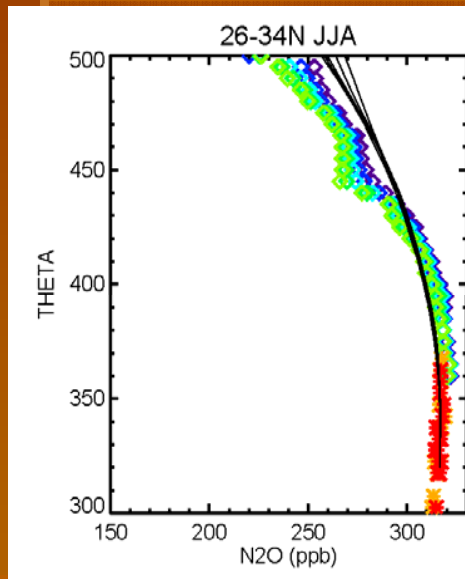
Polar



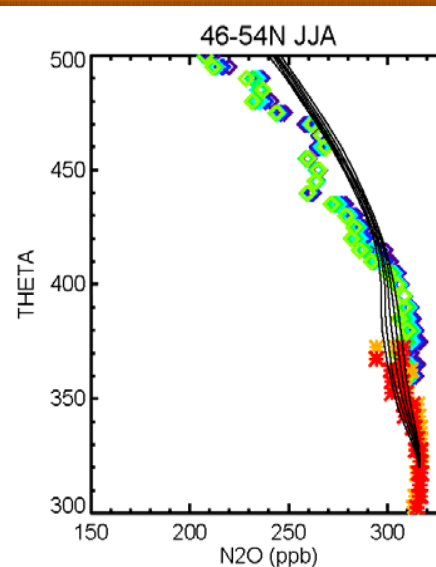
Combo (black), ER-2 (blue/green), Spurt (Red). This shows the worst agreement of all seasons. *This '1996', a very warm Arctic winter!*

Simple evaluation of composition: Combo N₂O + Spurt and ER-2 Summer Profiles

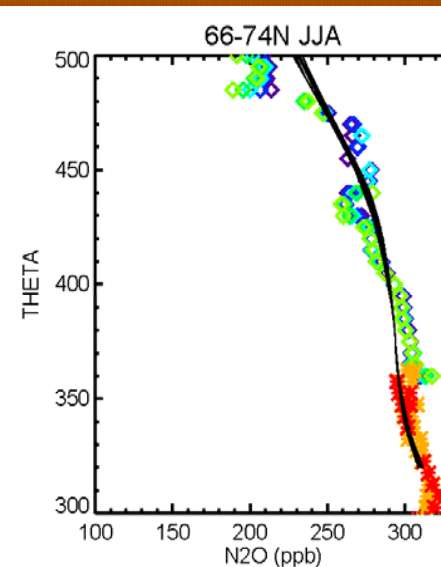
Subtropics



Midlatitudes



Polar

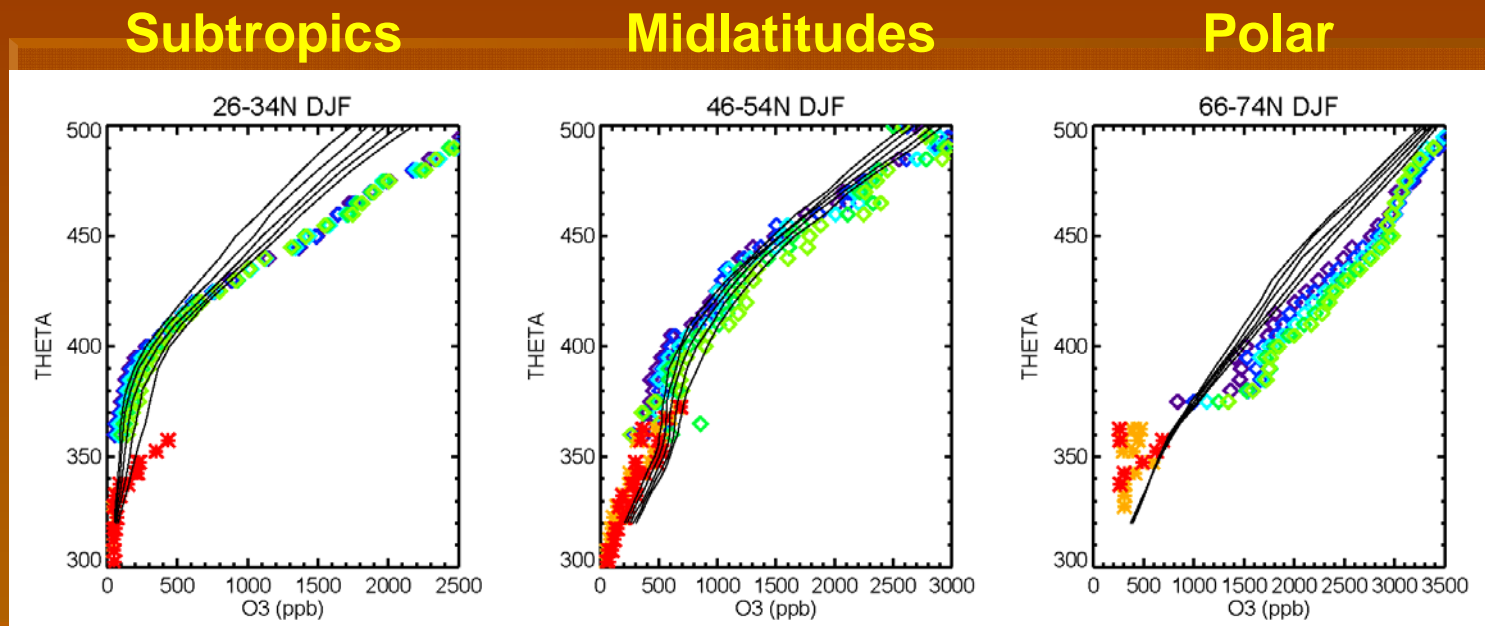


Combo (black), ER-2 (blue/green), Spurt (Red). The agreement shown here is typical of spring and fall too.

Year-round, agreement is very close in the midlatitudes. In the subtropics, N₂O is systematically a little high above ~430K.

NEED TO COMPARE WITH GMI STRAT MODEL – CHEM OR TRANSPORT?

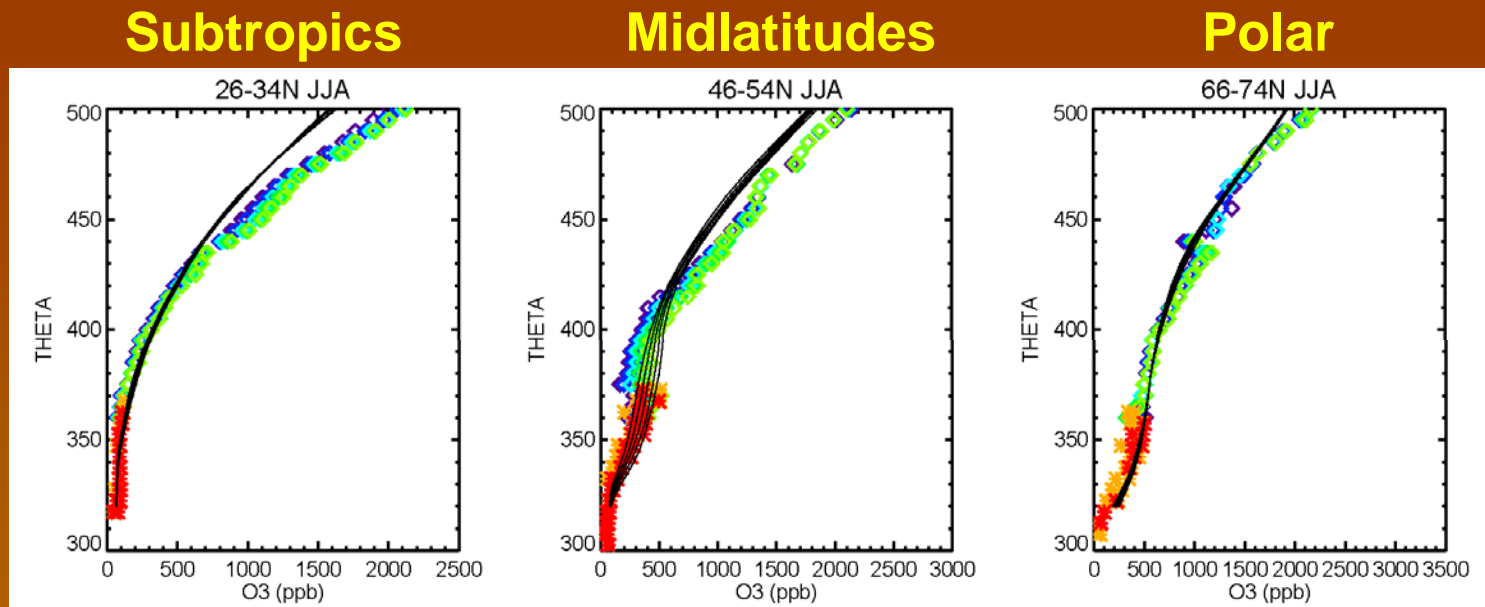
Simple evaluation of composition: Combo O₃ + Spurt and ER-2 Winter Profiles



Agreement in the midlatitudes is consistently excellent in the lower stratosphere.

This is the first time we have seen O₃ too low in the polar lower strat (Fast JX?). *This is only 1 year of the 5-year run – and the warmest one.*

Simple evaluation of composition: Combo O₃ + Spurt and ER-2 Summer Profiles



This is our best ever summer polar O₃. Summer has the poorest agreement for the midlatitude lower stratosphere. The subtropics are consistently a little low above ~430K.

Spring and fall agreement are similar to summer.

The lowermost stratosphere agreement looks very good everywhere.

The average global column is lower than TOMS by ~20 DU. It is also lower than the Hindcast simulations (by 6 DU) which had no tropospheric ozone. The primary difference with the Hindcast stratosphere is the lower stratosphere.

Evaluation of Tropopause Region Structure: Combo CO Profiles and the Dynamical Tropopause

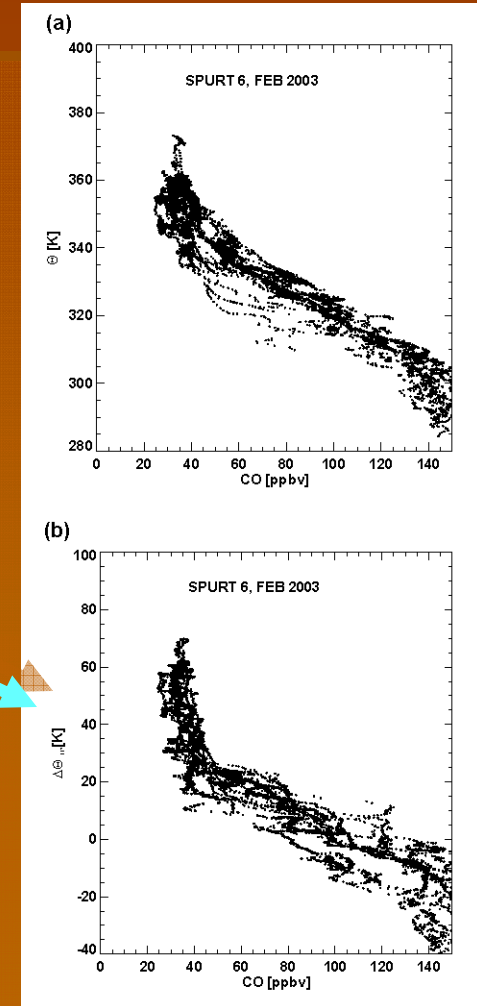
The dynamical tropopause is defined by the 2 PVU surface. This tends to be slightly below the thermal tropopause.

Aligning CO vs potential temperature profiles with respect to the dynamical tropopause removes significant variability (Hoor et al., 2004]

CO profiles show 3 distinct regions: the upper troposphere (high), the stratosphere (~ 40 ppb and below), and the tropopause region.

Theta

Height (K) above TRPP



CO (ppb)

Evaluation of Tropopause Region Structure: Combo CO Profiles and the Dynamical Tropopause

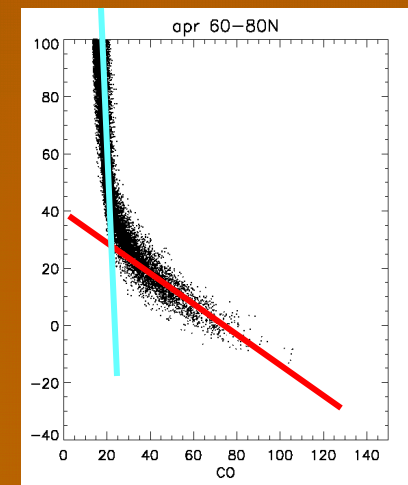
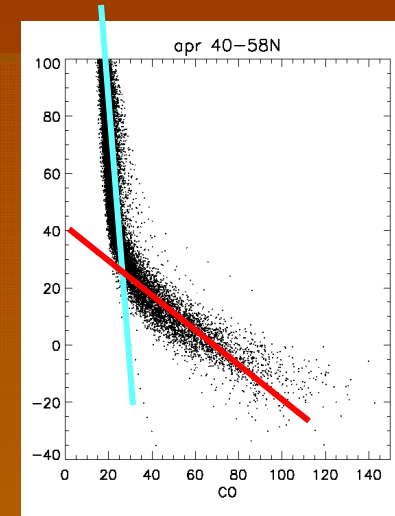
From the Spurt CO Analysis:

A mixing line connects the trop and strat.
The transition to a stratosphere CO 'lapse'
rate marks the top of the mixing region.
The thickness of this region is remarkably
constant in the extratropics in all
seasons.

From our Combo Model (April, right):

The transition to the stratosphere CO profile
occurs ~25-30K throughout the extratropics.
Typical model upper tropospheric CO is
~65-140 ppb.
The transition to stratospheric CO is ~25 ppb,
while the Spurt transition is 40-45 ppb.

Height (K) above the TRPP



CO (ppb)

Evaluation of Tropopause Region Structure: Combo CO Profiles and the Dynamical Tropopause

From our Combo Model (August, right):

The top of the mixing layer is $\sim 25\text{--}30\text{K}$ above the tropopause in summer.

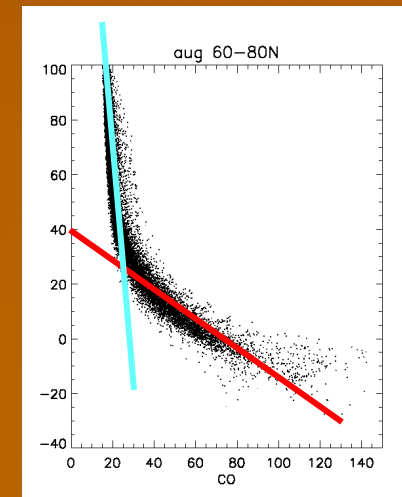
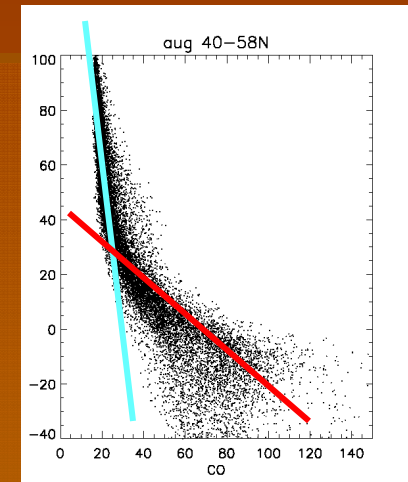
Some mixing lines appear to extend into the UT.

Conclusions about the Combo Model:

The thickness of the tropopause mixing region is $\sim 25\text{--}30\text{K}$ throughout the extra-tropics, all months. Very good agreement with Spurt.

But...is there too much stratospheric CO in the UT? And is there too little tropospheric influence above the mixing region (i.e. CO is too low). TBD.

Height (K) above the TRPP



CO (ppb)

Evaluation of other influences in the Mixing Region: Spurt CO₂ Seasonal Cycles across the tropopause

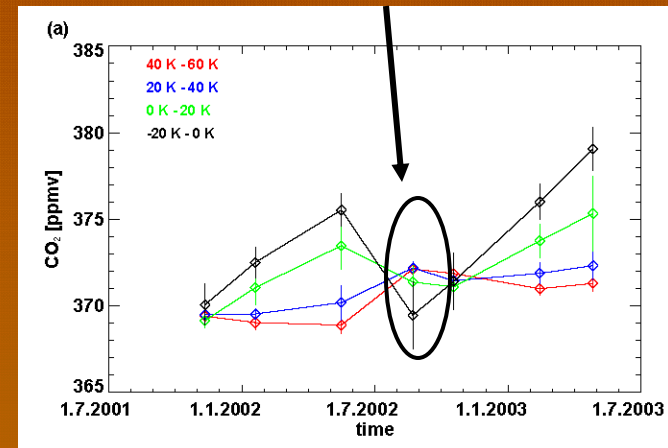
Hoor et al. [2004] observed a late spring maximum in the upper troposphere and in the mixing region (black and green lines).

They observed a ~ 3 month lag in the arrival of the maximum at $>20\text{K}$ above the dynamical tropopause.

Conclusion: the mixing region is strongly coupled to the troposphere, but above it, the stratosphere is influenced by air that entered through the tropical tropopause.

Consistent with ER-2 data CO₂ analyses of Boering et al. [1994] and Strahan et al. [1998].

The vertical gradient is reversed in August!



Black is UT, Green is TRPP, Blue and Red are above the Trpp/mixing region.

Evaluation of other influences in the Mixing Region: Combo CO₂ Seasonal Cycles across the tropopause

The figure shows 1-year time series of Combo CO₂ below, at, and above the tropopause.

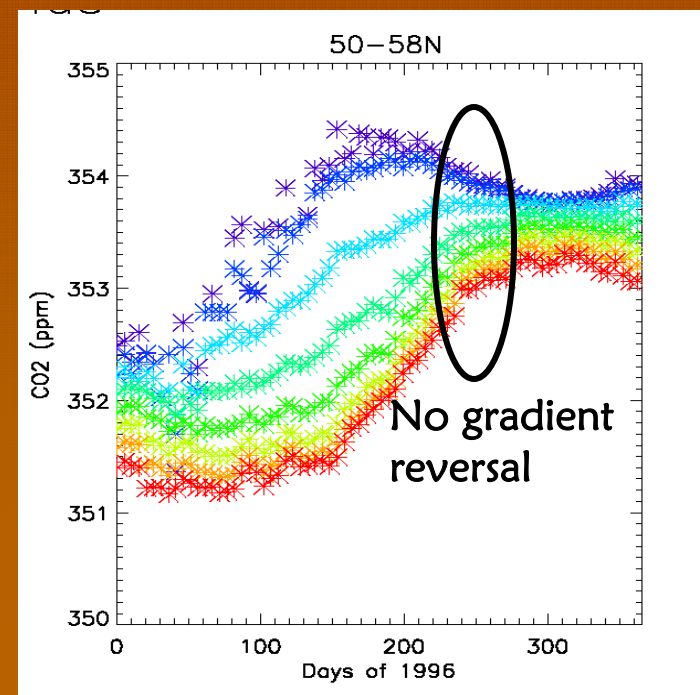
Blue/Purple: both in the UT, very similar

Sky Blue: the tropopause, distinct from the cycles above and below. Has the smallest seasonal amplitude.

Green/Yellow/Red: >20K above the tropopause. Fairly clustered. Cycle maximum 3-4 months later than UT maximum.

We do NOT see the vertical gradient reversal in summer because we do not have low summer values in the UT (because convection was turned off).

Combo CO₂



The tropopause level is Sky blue.

Preliminary Conclusions about the extratropical tropopause region of the GMI 2°x2.5° Combo Model with FVGCM met fields

- Ozone profiles, when viewed in a dynamical coordinate system, agree quite well with aircraft data between the tropopause and about 50 hPa (~500K). Some low bias in the subtropics above 430K.
- Differences between model and obs are smaller than have seen in previous GMI stratospheric simulations. N₂O profiles also show better agreement than before. (Transport and/or Fast-JX?)
- The region just above the tropopause, where the stratosphere and troposphere interact, has similar physical characteristics in the model and the observations. It has the same thickness (~25K) and shows no seasonal variation.
- The model stratosphere could have too strong an influence here. Additional evaluation of the composition of the mixing region (e.g., determination of the fraction of strat air) is needed.